Selforganisation of the Sensorimotor Control in an Autonomous System Using Genetic Algorithms

Susanne A. Huber, Hanspeter A. Mallot, Heinrich H. Bülthoff
MPI für biologische Kybernetik, Spemannstr. 38, 72076 Tübingen, FRG.

In natural evolution the sensor and motor system did not develop independently from each other, but as a closely coupled system. In order to investigate this coupling, we study autonomous systems in a simulated environment with sensors and motors acting *in a closed loop of perception and action, i. e. in permanent sensorimotor interaction.* This is in contrast to the traditional approach of information processing where the architecture of a system is decomposed into the functional modules of sensor input, central processing and motor output. We use genetic algorithms to evolve visually guided control mechanisms and a sensorimotor coupling to enable the agent to avoid obstacles and to stabilize its course, i. e. to compensate for rotations caused by external disturbances. The design of the agents is based on neurobiological principles that underly various aspects of insect navigation. For our artificial system, the most important biological insight is that insects navigate mostly by evaluating visual motion information by means of neurons tuned to specific motion patterns. The spatial localization of the receptive fields of these neurons is optimized with respect to certain behavioral tasks.
Our autonomous system has four visual sensors and two actuators. Two sensors combine to a motion-detector and the outputs of the two detectors are transmitted to the motors. We assume bilateral symmetry of the motion detectors and the transmission weights from the motion detectors to the motors (fig. 1a). The free parameters of the system are (i) the viewing directions of the sensors which implicitely define the preferred motion vector of the detectors and (ii) the transmission weights. The agents navigate in a tunnel with sinusoidal patterns on the walls and obstacles (fig. 1b).
Genetic algorithms are used to evolve the sensor directions and the transmission weights between sensors and motors. These algorithms simulate evolutionary adaptation of a population of individual agents via processes of selection, mutation, reproduction and recombination. Individuals of high fitness can recombine to new individuals by crossing over their genetic material or produce offspring that are genetically identical to the parent. Mutation can change the structure of each individual. The individual with the highest fitness is transferred to the next generation without modification.
With a population size of 100 individuals, agents evolve that can compensate for external disturbances and navigate through unknown environments without colliding with obstacles. Their architecture allows the agents to generalize the behavior to different environments. They are tested in tunnels that are up to 10 times longer than the tunnels used during the simulated evolution. During the test phase we add noise of ±10% to the sensor input and motor output and vary the starting position of the agent (see fig. 1). Under these conditions, it successfully navigates the tunnel in 70% of the trials.

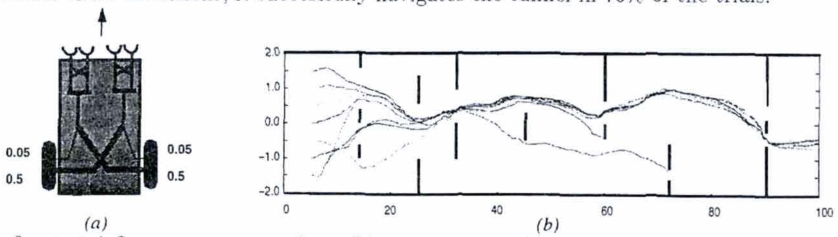

fig. 1: (a) Sensorimotor–coupling, (b) Paths in tunnel with variing starting positions